Application of unmanned aerial vehicle in power grid inspection

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ABSTRACT

This paper explains the current application status and future development space of unmanned aerial vehicle (UAV) assisted power grid inspection. Based on existing technical research and practical applications, this paper analyzes and prospects from four aspects: channel inspection, tree obstacle inspection, detailed tower inspection, inspection data management and application. The research shows that the UAV-assisted power grid inspection technology has entered a rapid growth stage from the exploratory stage and has a broad application prospect.

Keywords: Unmanned aerial vehicle, power grid inspection, tree obstacle inspection, detailed inspection

1. INTRODUCTION

With the development and widespread application of drone technology, the application of drones in the power grid field has extended from the preliminary survey and design of the power grid to the operation and maintenance of the power grid. There has been tremendous development in its application fields, technical means, and associated extensions. The application of drone technology in power grid inspection has entered a rapid growth phase from the exploratory stage of operation and inspection mode. The following characteristics exist (1) Traditional information acquisition methods and a single source; (2) Equipment status Perception still exists. The main methods are power outage maintenance and offline experiments; (3) The data utilization rate of online monitoring, hot maintenance, robots, drones and other advanced means is low. Under this condition, we are supported by the modern information technology of the “Big Cloud, Internet of Things, Mobile and Internet” intelligent operation and inspection concept Emerging as the times require. Drone-assisted power grid inspection is an important part of the three-dimensional inspection system based on intelligent equipment. Based on the current situation and possible development direction of drone-assisted power grid inspection, this article elaborates on five aspects: channel patrol, tree obstacle patrol, refined patrol of poles and towers, patrol data management and application, and foreign matter removal.

2. CHANNEL PATROL

According to the “Regulations on the Operation of Overhead Transmission Lines”[1], the channel patrol inspection is to inspect the line channel, surrounding environment, crossings along the line, construction operations, etc. The objects of the line channel patrol inspection include buildings (structures), trees, construction operations, mining impact districts, fires, crossing, flood prevention, drainage, infrastructure protection, roads and bridges, pollution sources, natural disasters, etc.[2,3]. Channel patrols can use visible light video or image capture to collect geographic information and data about the corridor environment. Distributed multi-rotor UAV patrols can be used for discrete distribution channel hidden dangers. For concentrated and continuous distribution, channel hidden dangers, fixed-wing patrols with high flight speed and long operation time can be used in UAV patrol inspection operations. Multiple choices wing is adopted When the UAV is patrolling, multiple options are available. The minimum safety distance between the UAV and the line tower should be greater than 2 m. When the UAV is patrolling, it is fixed wing. The minimum safety distance between the UAV and the line, tower or pole should not be less than 100 m, and the height from the UAV to the top of the tower should not exceed 300 m. In order to improve work efficiency, the accuracy of the coordinates of the line, tower, or pole should be guaranteed. Production requires an orthophoto of line corridor or quick image matching. Single-camera back-and-forth flight or combined inclined-camera one-way flight can be adopted for areas with poor image texture.

At present, channel patrol is defined as the inspection of the line corridor environment on a macro level. When operating drones, automatic flight is often used. When using image shooting for operations, many automatically captured images

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and a large amount of data are captured. When using video shooting for operations, it is affected by limited image transmission, Effective distance, and the inability to browse video data in real-time on the ground. In order to improve the effectiveness of inspection work, it is necessary to quickly browse and analyze video or image data after the plane returns to the ground and roughly determine the location of some emergency hidden dangers (such as fire hazards). In order to achieve this inspection requirement, it is necessary to study the technology of quick images or videos and automatically generate reports so as to realize the rapid re-confirmation and detailed investigation of hidden dangers in critical areas.

3. TREE BARRIER PATROL

The so-called hidden dangers of tree barriers refer to the situations that endanger the safe operation of overhead power lines due to trees within the protection range of the lines, collectively referred to as hidden dangers of tree barriers. Tree barrier accidents refer to power accidents above level 2 caused by tree barrier problems. Using drones to obtain visible light images for tree barrier measurement is an emerging technology in recent years. Compared with traditional tree barrier measurement methods, drone visible light tree barrier measurement has the characteristics of flexibility, simplicity, and strong visibility. With the development of lidar technology, drones can already carry lightweight lidar equipment for tree barrier patrols. Although drone lidar has advantages in measurement accuracy, it is expensive and complex to operate and requires a professional team to complete. In comparison, drone visible light tree barrier patrols are more straightforward, portable, safe, and reliable and have significant advantages in tree barrier prevention and measurement. The comparison between visible light and lidar in tree barrier patrols is shown in Table 1.

Table 1. Comparison of visible light and airborne laser.

Index	**UAV photogrammetry**	**Airborne scanning**
Technical level	Mature technology, high degree of automation, and rich data product achievements	Novel technology, relatively not very mature, large data volume, high degree of automation
Cost control	Low cost	High cost
Operation implementation	Simple operation, low requirement for operator	Complex operation, high requirement for operator
Efficiency	High	Low
Measurement accuracy	Submicron level	Centimetre level

According to the relevant regulations in the "Operating Procedures for Overhead Transmission Lines"[1], the safe distance between conductors and trees at maximum Sag and maximum wind deflection is shown in Table 2.

Table 2. The safety distance between trees and most arc sag, most wind deviation.

Line voltage	**66-110**	**220**	**330**	**500**	**750**
Vertical distance at maximum sag/m	4.0	4.5	5.5	7.0	8.5
Clearance distance at maximum wind deviation/m	3.5	4.0	5.0	7.0	8.5

Based on the safety distance mentioned above, the hidden danger level of tree barriers is derived and divided into three levels: emergency, primary, and general, according to the severity of the hidden danger. There is yet to be a unified industry standard to regulate the above classification levels uniformly. Assuming that the safety distance between trees and conductors under different voltage levels (as shown in Table 2) is D, the State Grid Corporation of China stipulates in existing operation documents that the distance between trees and conductors is defined as general when it is between D and 0.9D, significant when it is between 0.9D and 0.8D, and emergency when it is within 0.8D. The Southern Power Grid Corporation of China stipulates in existing operation documents that the distance between trees and conductors is defined as an emergency when it is within D, significant between D and D+3, and general when it is within D+3 and D+9.

The current principle of visible light tree obstacle measurement is based on the collinear equation of photogrammetry through the image coordinates of the corresponding points on the Material side. The parameters of the approximate catenary equation are solved to fit the spatial position of the entire wire. The accuracy of this fitting algorithm depends on the accuracy of the image's spatial three-dimensional solution and the corresponding points' subsequent measurement accuracy due to the wire Sag. The image of temperature changes greatly, and increasing the temperature coefficient in the current simulation calculation formula will Reverse the derivative multiple. The spatial position of the wire under temperature conditions is for line operation maintenance work to provide a more comprehensive reference basis.

4. DETAILED PATROL INSPECTION OF THE TOWER

The acceptable inspection of UAVs refers to the inspection of poles, tower bases, conductors, ground wires, grounding devices, insulators and auxiliary settings. Collection high inspection method is used to defect and hidden danger analysis by distinguishing images (including light and infrared images)[4]. The most significant feature of detailed inspection in data collection is the need for hovering and close-range photography. Currently, multi-rotor drones are commonly used for detailed inspection, with the aircraft manually controlled by personnel during the inspection and at the same time through real-time image transmission judgment. The distance and time of the shooting. The sensors used are mostly zoom cameras and infrared and ultraviolet equipment. After the data collection is completed, the data needs to be sorted and analyzed. Currently, the defect and hidden danger information are basically interpreted and analyzed manually, and a report is finally formed--different tower pairs. The shooting location has different requirements. Taking the single-circuit linear tower as an example, the shooting position is shown in Figure 1[5].

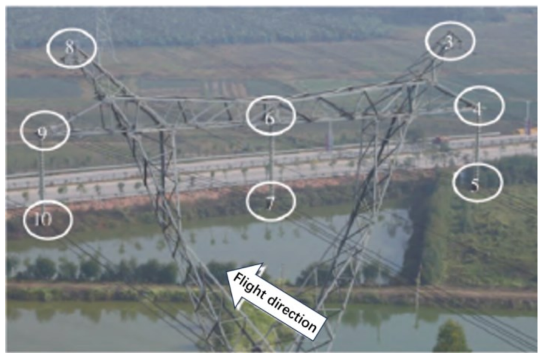

Figure 1. Requirements of the single-loop straight tower with visible light image.

In order to achieve the purpose of intelligent inspection, there are many methods for optimizing the inspection path of transmission lines. Li et al.[6] proposed a method for optimizing the inspection path of transmission lines based on the DEDSO algorithm, which considers the risk probability of poles and towers. Yang et al. proposed an improved RRT*FN path planning algorithm[7]. The methods such as equivalent the inspection path to a standard traveling salesman problem (TSP) without reaching the starting point to solve[8]. Li[9] introduced an ultrasonic obstacle avoidance method based on fuzzy control, established fuzzy rules for drone obstacle avoidance, and realized the optimization of the inspection path. The above methods mainly consider optimization algorithms for relatively long-distance shooting outside the electric tower and are all verified by simulation experiments. They are considering the ultra-close distance of the present detailed inspection meter level.

The current situation is that there needs to be an effective automatic inspection method for optimizing the complex tower equipment and environmental conditions. In response to this situation, this paper proposes a method for completing detailed inspection operations based on learning and automatic inspection modes. This method is based on RTK centimetre-level positioning. The precision multi-rotor UAV records the flight trajectory and sensor actions in learning mode through the intelligent control terminal of the UAV. The recorded information will be used as the basis for flight in automatic inspection mode. Automatic inspection can be carried out according to the information recorded in learning mode in automatic inspection mode. This inspection method effectively solves the problem of fine inspection of complex poles and towers at close range. However, this method also needs to solve the problem of automatic UAV control in complex environments and power supply in electromagnetic solid environments. Patrol height precision positioning aviation operations and other technical problems so as to improve the safety and efficiency of automatic and detailed inspections.

5. PATROL DATA MANAGEMENT AND APPLICATION

The widespread application of UAV technology in power grid patrol inspection operations has improved the efficiency and quality of patrol inspection. However, the data collected by UAVs have characteristics such as high resolution, high timeliness, large volume, and short repetition cycles, which require timely, rapid analysis and efficient management of the data after obtaining them.

5.1 Image processing and analysis

In recent years, with the continuous development of computer image processing technology, the requirements for intelligent analysis of inspection images are getting higher and higher. Zhang[10] transformed rusty colour images into grayscale images, proposed a super-red method to grayscale rusty images, and applied multiple rusty grayscale images for least squares fitting to determine the location and size of rust defects segmentation of closed value range to achieve automatic recognition of corrosion defects in transmission lines. Han et al.[11] proposed a method to integrate multiple-source information. The power tower detection framework model automatically detects the precise location of the tower and judges the abnormal state of the tower. Zhang[12] proposed, based on OpenCV graphics and image processing methods, aiming at the abnormal inspection diagram of insulator string falling, transmission line bifurcation and suspension DirtA better recognition method has been proposed. In general, the application of image processing technology is still mainly focused on image stability and quality improvement. The core issues of inspection are state monitoring and fault diagnosis. This core, the intelligent research of the problem is basically based on target extraction and recognition, and fault diagnosis is carried out through pattern recognition methods. The defects and hidden dangers that this kind of method can discover include insulator pollution, bursting, tilting, medium and large-scale tower material missing, and foreign matter suspension. However, intelligent image analysis requires high quality and precision of the original image, and the data must be applicable to specific algorithms; current research can only automatically detect some defects and hidden dangers.

In view of the massive amount of raw data, under the current technical conditions, it is indeed possible to achieve the regular operation of the power grid. Image processing and analysis should also be based on a comprehensive and auxiliary artificial intelligence analysis system. Relevant auxiliary functions should include the following aspects:

(1) Establish a defect database and design a flexible and scalable coding standard. Implement standardized coding for images, data, defect database, and other detailed inspection images and process results files of transmission lines.

(2) Spatial and temporal clustering preprocessing of the original drone photos through spatial and temporal special effects to achieve the tower, circuit, three phases, etc. Three-level photo classification to establish linear topology management of defect photos.

(3) Provide a visual method to assist in rapid defect identification and classification by human operators. The system analyzes equipment defects based on the data from the accounts and geographic information, guiding maintenance operations. It automatically generates detailed and visually appealing defect reports, completing the entire defect report generation and management process.

5.2 Inspection management

In view of the characteristics of inspection data, the integrated management system based on geographic information systems has become the first choice for intelligent data management. The integrated management system based on geographic information systems can support the massive original data obtained by drones and associate the data with the actual spatial location, supporting multi-source. The data comparison analysis and integrated application support query analysis and three-dimensional visualization, achieving scientific management of inspection data.

Based on the requirements of the intelligent three-dimensional inspection system, the development prospects and directions of UAV inspection management are as follows:

(1) Establish a data centre based on big data fusion. Establish a big data analysis centre to analyze massive data such as video, laser point cloud, oblique photography, and high-definition images, establish a typical equipment defect library and a typical defect expert knowledge base, and intelligently analyze the real-time status of the line channel environment.

(2) Establish and improve the closed-loop management process and technical support platform for mobile inspection operations. Establish a closed-loop management process for UAV inspection planning, inspection execution, fault repair, and result feedback. This process must be supported by a unified platform with inspection data processing and auxiliary analysis functions, enabling lean three-dimensional inspection system management.

6. CONCLUSION

UAV assisted power grid inspection is an important part of the three-dimensional inspection system based on intelligent equipment, and it is an important aspect of current inspection technology research. UAV-assisted power grid inspection can effectively solve the problems of heavy workload, low efficiency, high risk of traditional manual line inspection, high cost of manned helicopter line inspection, complicated flight approval procedures, and many restrictions on the operation environment. With the development of drone industry application technology, UAV-assisted power grid inspection will provide a safe, efficient, and comprehensive inspection mode for power grid inspection to meet the needs of daily power grid inspection, fault patrol, and emergency rescue.

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